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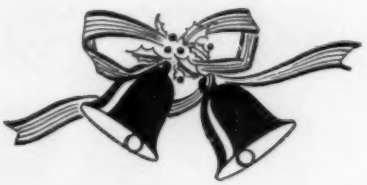

Lubricating Grease Requirements for Modern Military Aircraft

Presented before the

Eleventh Annual Convention of the National Lubricating Grease Institute

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Note—This paper presents the views of the authors as of this date and does not necessarily constitute an official statement of the Materiel Command.

I. Introduction:

Modern military aircraft depend on lubricants for proper functioning to perhaps a greater extent than any other piece of military or commercial equipment. Aircraft engines in themselves are very broad in their requirements while other moving parts, particularly the control system, provide an entirely different set of conditions. A number of frictional surfaces are known which will operate satisfactorily without lubrication, but in most of these cases it is necessary to apply some sort of greasy material to prevent rusting, which would hinder or prevent operation. Relatively long periods of idleness during bad weather or repairs increases the need for rust preventive lubrication. Because of the difficulty of relubrication of many parts and to eliminate plumbing, greases are used to a great extent and, in order to satisfy the many requirements, several different types and grades are required.

The range and speed of present aircraft, which will probably be further extended, pose lubrication problems not encountered in other transportation. Not only does temperature vary sharply with altitude but a modern transport plane may move from summer to winter ground conditions in 24 to 48 hours elapsed time. Light weight equipment means more pay load, at least double the weight saved. In power producing mechanisms light weight means high speed and so the high speed electric motor becomes useful. More items of lubricants increases the probability of mistakes, increases cost of operation and supply difficulties. The problem therefore becomes one of selecting the fewest possible number of greases to meet the necessary requirements of temperature range, speeds, loads and nature of applications. Good stability, both chemically and physically, is required and each grease should have as many desirable performance properties as possible in order to permit the minimum number of greases and relubrications.

This paper will attempt to inform the grease manufacturer who has not made a study of aircraft lubrication, concerning the grease requirements for military aircraft. It will explain why these requirements are thought to be justified. For those grease manufacturers who have been in close contact with aircraft manufacturers it may present a general picture including some points not encountered by their own work. The paper will be general in nature but will try to give a sufficient number of specific examples to establish certain requirements. It will also discuss current methods used for the examination of lubricating greases and the author's views concerning the construction of specifications for aircraft greases.

II. General Requirements:

In any discussion of the lubrication requirements for military materiel, three essential considerations must always be borne in mind. First, the lubrication characteristics and demands of the part being lubricated. Second, the availability of the lubricants required. Third, the problems of supply in the field. From the standpoint of good logistics, it would be very desirable to be able to lubricate all parts with one grease in the field, or better yet, have all parts so designed and lubricated that no further servicing would be required after the airplane left the manufacturer's plant. The lubrication requirements of aircraft components are so exacting and so broad, that a single satisfactory grease could only be described in Hollywood's super colossal adjectives. Since there is no such material at the present time, the problem becomes one of supplying the minimum number of greases obtainable in adequate quantities, that will do a satisfactory job over the entire range of operating conditions. Gentlemen, the field of grease research and development is wide open and we have "not yet begun to fight".

The range of temperatures over which aircraft greases are expected to give satisfactory performance is probably the most severe requirement to be met and is one of the important factors which set aircraft lubrication apart from lubrication of ground equipment. Aircraft and equipment must be kept to a minimum weight; this tends toward reduction of torque available for overcoming the frictional resistance of the grease and toward high temperature rises in some lubricated parts.

After careful study of available data, the range of ambient air temperatures at which satisfactory operation of all aircraft is expected, is defined at the present time as −65°F to +160°F. Actually, the range of ambient temperatures may be somewhat broader. Data recently reported by Klein (1) indicates that temperatures as low as −120° F have been measured at 53,000 ft. It was further pointed out that temperatures at high altitudes are lower over the equator than at the poles. On the high end of the range, temperatures as high as +180°F have been measured in closed-in compartments of aircraft in the hot desert sun.

The actual operating temperature range is, of course, broader than that for ambient temperatures due to temperature rises in the lubricated parts. Such temperature rises are most serious in the case of engine accessories, where the bearings receive heat from the engine as well as from sources normally causing a temperature rise. The normal operating temperature range to which grease may be subjected can be considered to be −65°F to +300°F, and with artificial heat being supplied at low ground temperatures −20°F to +300°F. Here again, we may occasionally expect temperatures beyond the range given. For example, a number of accessory manufacturers have stated that bearing temperatures as high as 350°F can be expected. It is realized that even the best lubricating oils begin to deteriorate rapidly at temperatures above 300°F and it is hoped that the high end of the temperature range can be kept within reason by improved design. A few examples of normal operating temperature ranges are given below.

Unit and Part	*Low Temp.*	*Normal Maximum Operating Temp.*
Generator Bearings	−30°F	250°F
Starter Gears and Bearings	−30°F	200°F
Magneto Bearings and Gears	−30°F	260°F
Wheel Bearings	−65°F	300°F
Electric Propeller Motors	−65°F	175°F
Inverters and Amplidynes	−65°F	220°F
Control Pulley Bearings	−65°F	175°F
Retracting and Flap Motors	−65°F	200°F

A most essential prerequisite of any aircraft component is absolute reliability. It is grim humor indeed to state that a defective airplane or component part will be cheerfully replaced if it fails to function in the air. Assuming that proper selection of grease is made initially, stability in storage and in service are the most important grease characteristics affecting reliable operation of lubricated parts. Storage stability is essential in two ways. First, we must be reasonably certain that grease applied in the field is the same material which met our specifications at the grease factory and upon which our recommendations for application were based. Instructions to the field on how to mix separated oil back into a grease or on how to use a grease which has completely liquified would not be appreciated even if it were feasible to publish such information. Second, grease applied to sealed and prelubricated anti-friction bearings used as spare part stock must be sufficiently stable to insure satisfactory operation of the bearing when it is used for repair of an essential component. Sealed bearings are not easy to relubricate in the field. While it is true that demand for supplies and spares is now such that ordinarily shelf life is unimportant, it is possible that grease may be stored at high temperatures or under other adverse conditions for a year or more. The requirement of service stability is that the grease not change in structure or composition for the overhaul life of the part lubricated. This can be considered of the order of 500 flying hours; more or less intermittently. Of course many of our aircraft may not be in the air that long but many may be serviceable for much longer time.

Two requirements for aircraft lubricating greases over which some difference in opinion exists at present are water resistance and corrosion prevention. The presence of water to a greater or lesser degree may always be expected depending upon the design of the part and conditions of operation. Sealed bearings in starters, generators may be thought to present no water and corrosion resistance problem, yet due to "breathing" of warm moist air and subsequent chilling appreciable moisture may condense in such locations. Wheel bearings, landing gear linkage and retracting screws on the other hand may be subjected to a water spray of considerable force on landing in wet locations or on shipboard. For such locations it might be expected that a completely water repellent grease would be most desirable. However, it is known that such parts lubricated with a water repellent grease have badly corroded, while soda soap greases have been used for aircraft wheel bearings for some time with little difficulty being reported. It appears that an ideal grease should:

(a) Resist washing action of water and be adherent to the surface lubricated.

(b) Absorb water to a limited extent without appreciable change in physical properties.

(c) Inhibit corrosion.

Knowledge of the actual requirements for extreme pressure properties for aircraft greases is limited. As might be expected, application of E. P. greases is generally required by highly loaded gears, screws and chains, although some applications have been found to heavily loaded needle bearings and E. P. greases are often used for plug valve lubrication. The need for E. P. grease is generally found by a process of

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trial and error. However, the uses of E. P. greases are not extensive in aircraft as not all gears, screws, etc., require such products although the trend toward using lighter oils in greases to obtain satisfactory low temperature operation will probably enlarge the extent to which such greases are applied. In this respect only the constant striving against weight probably aids the performance of the lubricants and has made the grease manufacturer's problems less difficult. To date, mild E. P. additives have been adequate for all applications requiring such properties. The most extensive application has been to retracting gears and screws.

A grease may answer all other problems to the nth degree, but if the grease is not clean, it no longer is a lubricant. Cleanliness is particularly important in the case of antifriction bearings. Generally, little trouble is experienced at the source of the grease and the problem of keeping a grease clean resolves to one of obtaining proper handling of lubrication in the field. The field problem is a difficult one at best and probably the surest solution would be to package all grease in tubes.

III. APPLICATION OF GREASE TO AIRCRAFT.

In this section we will attempt to describe the grease requirements of the various types of aircraft components.

Lubrication of antifriction bearings probably represents the most important and at the same time, the most difficult grease problem on the airplane. It is in such applications that the greatest extremes in temperature of operation are encountered and the fact that such bearings are used indicates that a high degree of performance is desired. However, the development of shielded bearings fortunately has made the problem easier from the standpoint of the grease manufacturer. This is particularly true of control pulley bearings where it is difficult to believe that aircraft were ever flown without such bearings. The light weight, high speed, and high out-put of aircraft electrical equipment such as generators, retracting motors and starters have made the use of antifriction bearings almost a "must" requirement. Nearly every type of antifriction bearing will be found in such equipment and the service will vary from light intermittent duty servo motors to high output, hot running generators. Approximately 70 to 80 percent of the bearings will be single row, either single or double shielded. Bearing speeds will run from 2500 RPM for aircraft generators, to 8000 RPM for continuous duty motors, 12,000 RPM for intermittent duty motors, and as high as 20,000 RPM for starters. An excellent discussion of various characteristics and design trends of aircraft electrical equipment has been given recently by Holliday (2). Variation in temperature rise and torque available tend to make the selection of the lubricant even more difficult. Generally speaking, for equipment running at low temperatures, or intermittently, and where low torque is available at low temperatures AN-G-3a type of grease is usually specified. For equipment such as dynamotors, where extra torque is available at low temperatures and where continuous running will cause a moderately high temperature rise, a medium grade soda soap grease is applied. For very hot running equipment, such as engine accessories, a very stable, high melting point grease is required. In such cases heat applied to the engine previous to start-up aids in solving the low temperature problem.

Wheel bearing lubrication represents a severe service somewhat different than in the case of electrical equipment. The service is quite intermittent, and since a great deal of heat is generated by the brakes in stopping heavy bombardment aircraft, the temperature rise may be high and may be rapid. A certain amount of water resistance and corrosion resistance is, of course, required in this application, and for this reason aluminum soap greases were used for some time. However, such greases will not stand the thermal shocks given in heavy, power braked wheel bearing service and considerable trouble has been noted in the grease running out over the brake surfaces. Use of sealed bearings is not practicable. Torque at low temperatures does not appear to be an important consideration in wheel bearing lubrication. Medium grade soda soap greases now appear to give best all-around service in wheel bearings with a somewhat heavier grade necessary when ground temperatures are high and operation is particularly severe.

On the other hand, temperature rise in operation does not apply in the case of control pulley bearings, but the lowest possible torque must be obtained at low temperatures in order to maintain maneuverability and to assure satisfactory operation of automatic flight control equipment. Shielded bearings help in this case, although satisfactory grease stability must be maintained as high as 180°F. Greases of the AN-G-3 types are applicable here, although it appears that better low temperature characteristics must be obtained to assure continued satisfactory operation at the increasingly higher altitudes being used by both military and commercial aircraft.

Propeller hub lubrication is not particularly difficult as regards high temperature problems. However, since the rate of pitch change should be kept as nearly constant as possible, adequate low temperature greases are demanded. In this application specification AN-G-3 grease appears to be most applicable.

Other applications of antifriction bearings include aircraft camera and radio equipment. In most of such applications high temperature stability is not too important, but with the "fly-power" motors used the best in low temperature grease characteristics are demanded. It is now indicated that greases similar to AN-G-3a, but with smaller low temperature torque are the answer to our problems in such cases. Several such greases are now available.

Lubrication of gears, screws, chains, and threads, of course, is somewhat different than lubrication of antifriction bearings. The low temperature problem is still paramount, but the temperature range required is not so broad. On the other hand, better load-carrying capacity, flowability, adherence, and corrosion resistance are required. In the case of starter gears, graphite grease made from a low viscosity numeral oil has been the rule. The reasoning behind this selection appears to be based partly upon the assumption that while the starter will not be relubricated in service, some graphite will remain to lubricate the gear surfaces in the event that the main body of the grease is centrifuged off the gears. However, no data have been shown to indicate that a mild E. P. grease with good low temperature characteristics would not do a better job and such grease is now being tested by the Materiel Command for the purpose.

High on the list of applications for gear lubricants are the various retracting gears and screws. In most of such applications a mild E. P. lubricant is required. Generally a light gear oil would be desirable, but design considerations are often such that a satisfactorily tight gear housing cannot be obtained. Here a light E. P. grease is applicable, and normally AN-G-10 grease is recommended for the purpose.

Various schools of thought exist on the topic of thread lubricants, and for this reason a wide range of products will be found available commercially. A perfectly machined thread should require no lubrication at all, but usually some lubricant must be applied in order to insure maximum linear engagement of the threads for best holding and sealing properties without galling or seizing of the threads. The problem then becomes one for an E. P. type material such as specification 3571 lead soap grease.

Other applications of grease to aircraft components include packing grease for coolant pumps. This application is similar in many respects to automotive water pump lubrication except that considerably higher temperatures are involved (of the order of 350°F) and better packing and lubricating properties are expected. No completely satisfactory grease has been found for this job, although a hard grade of graphite grease will perform fairly well.

The "chassis" lubrication of an airplane consists of lubricating the pivot points on the various landing gear linkages. About 75 percent of these are plain bushings, the remainder, needle bearing. All are lubricated thru conventional pressure gun fittings. Here water and corrosion resistance are the grease properties to consider, as well as adherence. Flowability at low temperatures, while not as important as in other applications, must also be considered. A heavy aluminum soap grease is applicable in the summer, while AN-G-3a is required in the winter. It is suggested that the intermediate type grease mentioned below should be adequate for year round use.

Lubrication of plug valves has also received some attention. Here, the grease must act as an anti-seize as well as a sealing compound. Gasoline insoluble greases, generally castor oil base materials, are often used for plug valve lubrication, and although such greases are not entirely satisfactory at low temperatures, they must be used on fuel line valves. On plug valves for other lines (except oxygen) AN-G-3a grease or its E. P. variation, AN-G-10 have been specified.

Finally, we come to enclosed universals, flexible shafts and flexible drive cables. Requirements here are for satisfactory low temperature torque and for the grease to satisfactorily fill the housing to prevent accumulation and freezing of water.

IV. Methods of Test and Specifications.

A specification should do two things. It should tell the manufacturer what the customer wants and it should tell the inspector how to determine whether or not the submitted grease is satisfactory. The two are not necessarily synonymous. Properties which are commonly used by the manufacturer to identify and control a product are not necessarily related to performance but it is believed that such properties may reasonably be included in the requirements of a specification. Likewise it is sometimes found that simply determined effects have or seem to have some association with phases of performance apparently not logically related. It is also noted that to prove that a certain property is not related to performance does not prove that it is not valuable for specification control. Carried to an absurdity this might be expressed as follows: No part of a ball cut into pieces will roll, therefore a ball will not roll. Specifically we may say that to prove that melting point, evaporation and bleeding of a grease separately considered do not indicate its high temperature physical stability, does not at all prove that the proper correlation and consideration of the three properties would be equally inadequate.

Another feature of specifications which will probably result in controversy in any large group is the extent to which the purchaser is reasonably justified in requiring uniformity in products purchased. In the case of lubricating oils and liquid fuels this is not a troublesome factor since such products which are suitable for a certain use are always similar in physical properties and appearance if not in composition. In the case of lubricating greases products of quite different feel and appearance may actually be suitable for the same applications. However if purchases are made of such apparently entirely different products it results in uncertainty and bad psychological reaction on the part of the operators using them. It is noted that the German aircraft greases are artifically colored, probably as a means of ready identification, but possibly also to provide more uniform appearance for different examples of the same material.

Army-Navy Aeronautical (ANA) specifications for greases usually provide for purchase of the grease only from approved sources and therefore require that manufacturers submit samples for qualification prior to acceptance of material on contract. This practice leads to the distinction between Qualification Tests and Inspection Tests. The qualification tests usually include one or more actual service tests in a representative piece of equipment. Inspection tests are limited to those tests which can be made in a reasonably short time, preferably not more than one day, and which serve to identify the product as equal to or similar to the sample originally submitted to qualification test and approved.

For the purposes of this paper the authors have divided tests of greases into four main classes as follows:

(a) Elimination of Undesirable Ingredients
(b) Flow-pressure Properties
(c) Stability
(d) Others

Tests to eliminate undesirable and contaminating ingredients include examination for odor and appearance, corrosion and solid impurities. A careful examination for homogeneity is believed to be an important item and by this is not only meant recording of oil separation but also of any tendency to surface oxidation, undispersed soap particles and irregular structure. This is an example of the illogical control tests mentioned above. It is believed by the authors and agreed to by at least some producer technologists that the fibre type of soda base grease is generally inferior to the smooth type, at least for anti-friction bearings. AAF specifications (3) have therefore required the smooth, non-fibrous or short fibre type, a point difficult to justify except by mutual agreement of producer and consumer. A corrosion test with copper (by the usual ASTM method) is considered justifiable for the information of the manufacturer. Solid impurities may be controlled by the ASTM test for Insoluble matter, preferably followed by further examinations as to the nature of any insoluble material found, or by low power microscopic examination of the grease itself.

The flow properties of greases are important in controlling loss of grease from housings, power requirements at low tem-

peratures and lubrication effectiveness (4). ANA specifications at present measure torque at low temperature in a Conrad, No. 204, 8-ball bearing. This is not considered the final and most desirable method. It was adopted because low torque of ball bearings at low temperatures is a most essential feature of aircraft operation. The original concept of this test, determination of shear at one torque and one temperature has been amplified by various operators to include the "Plasticity Number", which equals torque times seconds for one revolution, at various torques and temperatures. The original method, still ANA specified, is a useful "go" and "no go" test. The plasticity number provides a better comparison of two or more greases. The AAF and Bu Aero. of the Navy Dept. are cooperating with the Coordinating Lubricants Research (CLR) Committee's Advisory group on greases in the evaluation of the Standard Oil Development (SOD) viscometer. This is a pressure orifice type instrument arranged for use over a wide range of high and low temperatures. The AAF is also constructing a concentric cylinder viscometer. It is evident that considerable study and test work is required before this important property of greases can be considered satisfactorily evaluated.

Allied to, but by no means directly related to, the shear or flow properties of greases is the ASTM Penetration Test for Consistency. First editions of ANA grease specifications did not include this test but it is now being added to all specifications following discussion with the CLR Advisory group. This is another and excellent example of a test which is slightly if at all related to performance values but is considered valuable for the following reasons:

(1) To inform the grease manufacturer concerning the general character desired.

(2) To control application properties, particularly of greases furnished in collapsible tubes.

(3) To aid the Inspector in identifying the qualified product.

(4) To improve confidence of the service personnel concerning uniformity and suitability.

Stability of greases is usually divided into two considerations, storage and service. For much aircraft use they are probably synonymous because of the small percentage of operating time in elapsed time. However, they will be considered separately. Storage stability is usually determined by actual storage by the manufacturer and by bomb oxidation by the purchaser. It is easy to criticize the former for lack of imagination and industry to produce a more rapid evaluation and it is equally easy to criticize the latter for lack of correlation and probable inaccuracy. It is difficult to suggest anything better. Bleeding and evaporating tests would appear to apply to both storage and service stability. No direct correlation has been made by Materiel Command laboratories or, as far as is known, by other laboratories. The methods and values specified in ANA specifications are descriptive of a few greases known to be generally satisfactory and superior to the older conventional commercial types. Mechanical tests for operating stability will be included in two ANA specifications, one now in preparation and one undergoing repairs, for high temperature, high speed greases. These will consist of various runs in carefully standardized ball bearings. It is to be noted that only individually checked bearings may be used for such work since the condition of the bearing is important in obtaining reproducible results. Test data in motors at 22,000 RPM previously obtained by the AAF and at 10,000 RPM to be obtained will be furnished to the Naval Engineering Experiment Station to aid in establishing specification limits on the Navy grease testing equipment. Some persons of considerable experience have advised the authors that penetration, melting point and bleeding after long working in the ASTM worker demonstrates service stability. It is certainly worthy of hope that the cooperating laboratories in the present CLR program will be able to evaluate a number of such procedures and that simple, easily standardized equipment will be proven adequate.

Miscellaneous tests of interest to the writer of specifications and the producer alike include melting point, water resistance, corrosion prevention and film strength. It is concluded that melting point is a justifiable specification requirement on much the same grounds as the penetration. Water resistance is the subject of a great deal of discussion whenever ANA specifications are being considered. It is hoped that the CLR Advisory group will have something definite to recommend in the near future. In the meantime the present Navy test will be continued. It is considered adequate, perhaps more restrictive than necessary. Corrosion preventive properties of greases should be studied. Some large consumers (5) have made considerable studies but data have not been collected and analyzed by any known authoritative cooperative group.

The primary function of a lubricant, that is its inherent tendency to reduce wear and friction of moving surfaces, is one of the most difficultly evaluated properties. The authors concur in the selection of the Four-Ball tester for the purpose. The calculation of pressure-wear index (P W I) (6) may appear needlessly and unjustifiably complicated to some but it is believed that analysis of the lubricating function will establish the desirability of the method. The extension of the range of boundary, lubrication is an important factor in preventing the occurrence of welding and consequent destruction of the frictional surfaces under conditions of incipient welding. A higher value for the P W I indicates a greater extension of boundary lubrication, that is, the range of incipient seizure without destructive welding. It is concluded from available data that a P W I of 15 provides adequate protection for all known aircraft gear installations with considerable margin of safety in most applications. It is suggested that a minimum value for the initial delayed seizure load should also be included in the Four Ball evaluation in order to properly define the minimum wear capacity of the lubricant. Data available are insufficient to establish the desired value at this time. Due to the highly controversial situation of wear testing no comparative discussion of the various machines in use will be attempted. It is believed, however, that expecting any one test machine to accurately rate all lubricants for all applications is a good deal like expecting one knock test engine to accurately rate all gasolines for all engines, a condition never indicated to the cautious and given up long ago by the more optimistic. The reasonable goal is a test which, by allowing a considerable margin of estimated surplus capacity, will insure satisfactory performance in the great majority of applications.

V. Summary of Aeronautical Grease Specifications.

A condensed summary of current specifications covering greases for military aircraft is given in Table I. The trend to be noted here is toward performance type tests rather than the older material requirements. The various applications of these greases are summarized in Table II.

While considerable progress has been made in the direction of simplification of grease specifications, examination of the above tables will indicate further improvement is necessary. The ideal would be one grease for all applications. At the present state of development of aircraft and the art of grease making, it appears that a goal of 4 greases is desirable and attainable, as follows:

(1) A low temperature grease. Such a grease should have satisfactory water resisting qualities and a range of satisfactory operation as nearly as possible to $-90°F$ to $+180°F$.

(2) An intermediate, general purpose grease. Such a material could have a temperature range of $-30°F$ to $+250°F$.

(3) A high temperature, heavy duty grease with desired low temperature limit of $0°F$ and a requirement for satisfactory life and operation up to $325°F$.

TABLE I

CONDENSED SUMMARY OF AERONAUTICAL GREASE SPECIFICATIONS

Grease	High Melting Point	Lead Soap Base	Low Temperature	Aluminum Soap Grade AA	Aluminum Soap Grade B	High Temperature Water Resistant	Graphite	Low Temperature E P	Gasoline Resistant
Specification No.	AAF 3560E Medium	AAF 3571B	AN-G-3a	AN-G-4	AN-G-4	AN-G-5	AN-G-6	AN-G-10	AN-G-14
Are Qualification Tests Required	No	No	Yes	No	No	Yes	No	Yes	No
General and Physical Requirements									
Color		Optional							Lt. Yellow to Brown
Odor		No perfume	No perfume nor rancidity	No perfume	No perfume	No perfume nor randidity	No perfume nor rancidity	No perfume nor rancidity	
Homogeneity	Note a	Note a	Note a	Note a	Note a	Note a	Note a	Note a	Note a
Penetration (worked, 77°F)	240-290	240-300	265-340 Notes (d) & (m)	310-340	355-385	Note (d)	320-380	310-385 Notes (d) & (m)	180-260
Melting (Dropping) Point, Min, °F	275°F		300°F Note (e)	190	250	375, Note (e)		300, Note (e)	260
Chemical Requirements									
Soap	70% Na + K, 10% Al	Note (b)	Lithium	Aluminum	Aluminum	Sodium	Usually Calcium	Lithium	Sodium and/or potassium
Ash, As soap base, Max., %				1.5	2.0				2-4
Oil Content, Min., %	83	75		87	86		80		75-87
Properties of Oil									
Color, ASTM, Max.	7			8	8				Note g
Viscosity at 210°F, SSU		140-220			178-218				
Viscosity at 100°F, SSU	200 Min.			232-312			190-325 (m)		5100-7900
Viscosity at 0°F, SSU	50,000 Max								
Viscosity Index					80				
Flash Point, Min., °F				290	500		300		420
Pour Point, Max. °F	0			-25	+30		-25		
Insoluble Matter, Max., %	0.2	3.0 (Tar)		0.2	0.2				Note i
Water, Max., %	0.5	1.0		0.5	0.3		1.5		2.0
Neutralization No.									10
Free Alkali (as NaOH) Max, %	0.1	0.2					0.10 (CaOH)		
Free Fatty Acid (as Oleic) Max., %	0.2	0.5					0.2		
Dirt Count									
Over 0.001 in dia., per cc			7,500					7,500	
Over 0.003 in dia., per cc			1,600					1,600	
Over 0.005 in dia., per cc			None					None	
Corrosion and Stability	Negative No Separation	Negative	Negative No Separation	Negative Homogeneous	Negative Homogeneous		Negative No Separation	Negative No Separation	Note h
Additives and Fillers	None	Note c	None	No fillers		No fillers	Note (f)	No fillers, EP Additive	No fillers nor rosin
Performance Test Requirements									
Low Temperature Torque									
Temperature, °F			-67					-67	
Torque, gm—cm			2000					2000	
Sec. for 1 rev, max, Orig.			15					30	
Sec. for 1 rev, max, after bleeding and evaporation			50 percent increase, max.					Max. 30% increase, 30 sec.	
Sec. for 1 rev, max, after 3 mos. storage			50 percent increase, max.						
Bleeding, max., %			5	16	5			5	
Evaporation, max., %			10					15	
Grease Loss, max., %			10					10	
Pressure-Wear Index								15	
Water Absorption, max., %			100			100		100	
Navy Grease Machine						Required, Note k			
Navy Beater Test						Required, Note l			
Oxidation, lbs. drop in 100 hrs.			5					5	Note j

(See Footnote at top of page 7)

NOTES:

(a) Smooth, Homogeneous, free from crusts, lumps., etc.
(b) Total soap 20% max., Pb soap 10% min.
(c) Fillers, none; sulfurized and chlorinated oils may be present.
(d) Normal range given; specification requires deviation from qualification sample ±10%, max.
(e) Melting point shall not differ from qualification sample by more than ±12.6°F.
(f) No fillers or rosin oils. 4 to 5% graphite (99%, min., graphitic carbon, 98%, min., 200 mesh, non-scratching).
(g) Vegetable (usually castor) oil used; Iodine No. (Wijs) max., 110; Neutralization No., max., 20.
(h) Grease shall not corrode copper at room temperature, 3 hrs.
(i) Grease shall be not more than 10% soluble in 40% aromatic gasoline.
Requirement may have to be revised, difficult to get greases which meet requirement.
(j) Layer grease, 1/8 in. on steel plate, 7 days at 212°F, shall not harden, separate, net change.
(k) Navy Grease Machine.

Run I, 600 RPM at 100°F.

(1) Torque at 15 sec., gm-cm, max., 200% (2).
(2) Torque at 5 min., gm-cm, 300-500
(3) Torque at 60 min., gm-cm., min. 75% (2)
(4) Leakage, %, max. 70

Run Ia, as above after 1 hr., at 2500 CM and 250°F.

(1) Torque at 15 sec., gm-cm. 50-150% of I (1)
(2) Torque at 5 min., gm-cm., 50-150% of I (2)
(3) Torque at 60 min, gm-cm, 50-150% of I (3)
(4) Total Leakage, %, max. 85

Run II, on Beater Residue, 600 RPM at 100°F.

(1) Torque at 15 sec., gm-cm., 70-200% of I (1)
(2) Torque at 5 min., gm-cm., 70-200% of I (2)
(3) Torque at 60 min., gm-cm., 70-200% of I (3)
(4) Leakage, %, max. 60

Run IIa, as for II after 1 hr. at 2500 RPM and 350°F.

(1) Torque at 15 sec., gm-cm., 50-140% of I (1)
(2) Torque at 5 min., gm-cm., 50-140% of I (2)
(3) Torque at 60 min., gm-cm., 50-140% of I (3)
(4) Total Leakage, %, max. 75

(l) Beater Test—After beater test grease shall be typical consistency, not granulated nor separated.
(m) Recommended values for changes now in process.

TABLE II

CONDENSED SUMMARY OF APPLICATION OF SPECIFICATION GREASES TO MILITARY AIRCRAFT

GREASE	SPEC.	GRADE	INTENDED APPLICATION
High Melting Point	3560-E	Med.	Ball and roller bearings where low temperature torque is not essential; e. g.; landing wheel bearings, dynamotor bearings.
Lead Soap Base	3571-B	—	Thread lubricant. Also may be specified for summer lubrication of heavily loaded gears where gear oils cannot be retained in housing.
Low Temperature	AN-G-3a	—	Ball and roller bearings, enclosed universals, tachometer shafts, slides and rollers where low torque at low temperatures is prime requirement. Examples; Control pulley bearings, retracting and flap motor bearings, flap guides and rollers, propeller hubs.
Aluminum Soap	AN-G-4	AA & B	Aluminum soap greases are used where water resistance, long retention, and corrosion resistance are more important than a wide temperature range of applicability. Not recommended for parts operating over 160°F. Grade AA for low temperatures, grade B for moderate summer temperatures. Grade B used for summer lubrication of landing gear linkage.
High Temperature Water Resistant	AN-G-5	—	Ball and roller bearings and related applications for extreme high temperature operation and where water resistance is a factor. Examples; Landing wheel bearings (summer, severe service) magneto and generator bearings. Not suitable where low temperature torque is critical.
Graphite	AN-G-6	—	Gears, bearings and chains where very infrequent lubrication is possible and where heavy sliding or shock loads are a factor. Not generally suitable for anti-friction bearings, electrical equipment or extreme high or low temperatures.
Low Temperature, E. P.	AN-G-10	—	Gears, screws, worms, chains, and plug valves where low temperature torque is essential and where better load carrying capacity than AN-G-3a is required.
Gasoline Resistant	AN-G-14	—	Lubrication of fuel pump bearings, plug valves for fuel lines, anti-seize compound, and as a gasket sealing compound.

(4) An E. P. variation of either 1, or 2, above.

VI. SUMMARY.

To summarize the points brought out in this paper.

(1) Aircraft requirements impose severe limitations on all lubricants, particularly greases.
(2) Military requirements impose further limitations.
(3) Although satisfactory greases are becoming available, considerable room for improvement exists.
(4) Development of test methods more accurately predicting serviceability should be continued in order to assist in the development of improved greases.

REFERENCES:

(1) Frank D. Klein, Use of Petroleum Products in Aircraft, SAE Jo., 51, 305 (1943).
(2) Lt. Col. T. B. Holliday, SAE Jo., 51, 234 (1943).
(3) AAF Specification 3560.
(4) J. O. Almen, Mech. Eng., 415 (June 1937).
(5) Private communications with motor manufacturers and other users.
(6) Specification AN-G-10.

Rubber Association Reports on Tire Shortage

A report on the tire situation is made to passenger car, truck, and bus owners in advertisements published recently by the Rubber Manufacturers Association speaking for 38 manufacturers and distributors.

"This is the situation today—the rubber supply crisis is past, but the long predicted and anticipated tire shortage is with us," the advertisement states.

Synthetic rubber became a source of supply "because government, the Rubber Director, and a group of industries—rubber, petroleum, chemical, alcohol—working together, compressed into less than two years a job that would normally have taken a dozen years."

Causes of a tire shortage, in the face of synthetic production, given in the advertisement are that the inventories of pre-war tires are gone, that military needs are beyond expectations, that rubber companies are busy making bullet-sealing gasoline tanks and other rubber war products, that the demand for large size heavy-duty tires is so huge, and that there is a manpower shortage in the tire as well as in other industries.

Reviewing the 1942 De Soto . . . What it Needs for '43

By WALTER E. BLAINE, Chek-Chart Detroit Field Engineer

The 1942 De Soto car is known as the Model S-10. While only one basic model was produced, several different DeLuxe and Custom models are included in the 1942 line as well as longer wheelbase (7 passenger) models.

The identifying serial number for each car is on right front door hinge pillar post, and may be easily read by merely opening the door.

Many service station operators are apt to assume that each and every pressure gun fitting on the chassis requires Chassis Lubricant, usually applied every 1,000 miles or every 60 days. While the majority of pressure gun fittings used on De Soto 1942 models do require Chassis Lubricant every 1,000 miles, the operator should make a careful inspection of the De Soto lubrication diagram to note exactly which gun fittings are not to be serviced with Chassis Lubricant or are to be lubricated at intervals other than every 1,000 miles.

Gun fittings using Chassis Lubricant at intervals other than every 1,000 miles or every 60 days are Torque Shaft, Gear Shift Control Bell Crank and Clutch and Brake Pedal Shaft. These 3 points require lubrication only every 6,000 miles and are reached from under the car, left side. The Universal Joint Spline requires Chassis Lubricant at 2,000 mile intervals.

Gun fittings using other than Chassis Lubricant and the interval at which they should be lubricated are the Water Pump, requiring Water Pump Grease every 2,000 miles, and the Propeller Shaft Center Bearing on 7 passenger models to which Wheel Bearing Grease should be added every 6,000 miles.

UNDER HOOD POINTS

The two generator oilers and the one starter oiler require Motor Oil every 6,000 miles. Do not apply more than six to eight drops to each.

The oil cup on the distributor shaft requires Motor Oil every 2,000 miles and the distributor cap should be removed every 6,000 miles to expose the rotor wick to which a few drops of Motor Oil should be applied.

The steering gear case requires SAE 90 Gear Lubricant the year round. Check level by removing fill plug.

OPTIONAL EQUIPMENT UNITS

Fluid Drive, Simplimatic Transmission, and Gear Shift Vacuum Cylinder features are optional on 1942 models. The functioning and necessary servicing of these units are the same as explained in a previous article under the heading of "Reviewing 1942 Chrysler Cars."

MISCELLANEOUS ACCESSORIES

Universal joints are of the needle bearing type and are packed at assembly. Joints should be inspected at regular intervals for leaking oil seals. If evidence of leaks is found, refer to a De Soto dealer. Three joints are used on 7 passenger models.

Rear springs have metal covers. If squeaks or hard riding occurs, lubricate by means of a special "C" clamp attachment, using semi-fluid grease without graphite.

The oil filter is of the sealed-in type. In renewing the element it is necessary to replace the entire unit. De Soto recommends that this be done every 8,000 miles or whenever the oil appears to be excessively dirty.

While the battery is not a lubrication point it sometimes is necessary that it be removed, and its removal at first appears to be almost impossible without first disconnecting the headlight control rod that operates the headlight shutter. To remove the battery raise the hood, disconnect the cables, remove the two nuts on battery, and hold down the clamps to permit the bolts to drop down out of the way. Lift the battery up about 1 inch and slide toward rear of car, then lift up and out of the car between the headlight control rod and fender.

Prelubricated points or points requiring no lubrication are the Fan, Clutch Release Bearing, Rear Spring Bolts, and Shackles.

Recap tires before carcasses are too far gone. Switch tires frequently. Because of rubber conservation, it has become almost universal practice to increase pressure slightly.

The crankcase on the De Soto holds 5 qts. The recommendation is for SAE 20 or 20W for temperatures down to +32°F., SAE 20W for lowest expected temperature of +10°F., and SAE 10W for lowest expected temperature of −10°F.

LUBRICATE FOR SAFETY EVERY 1000 MILES